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INT CL⁷ G01S 5/04 5/06
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(54) Abstract Title

# Position determination

(57) A system which monitors the positions of players, the ball and officials on a football pitch 10 uses unsynchronised, spread spectrum, frequency hopping transmitters attached to each player and operating intermittently on common frequencies. Direction finders 16, which use amplitude or phase comparison monopulse techniques, are located near each corner of the pitch; the directions to the transmitters give their positions. Each player has a different spreading code or frequency sequence which identifies him.

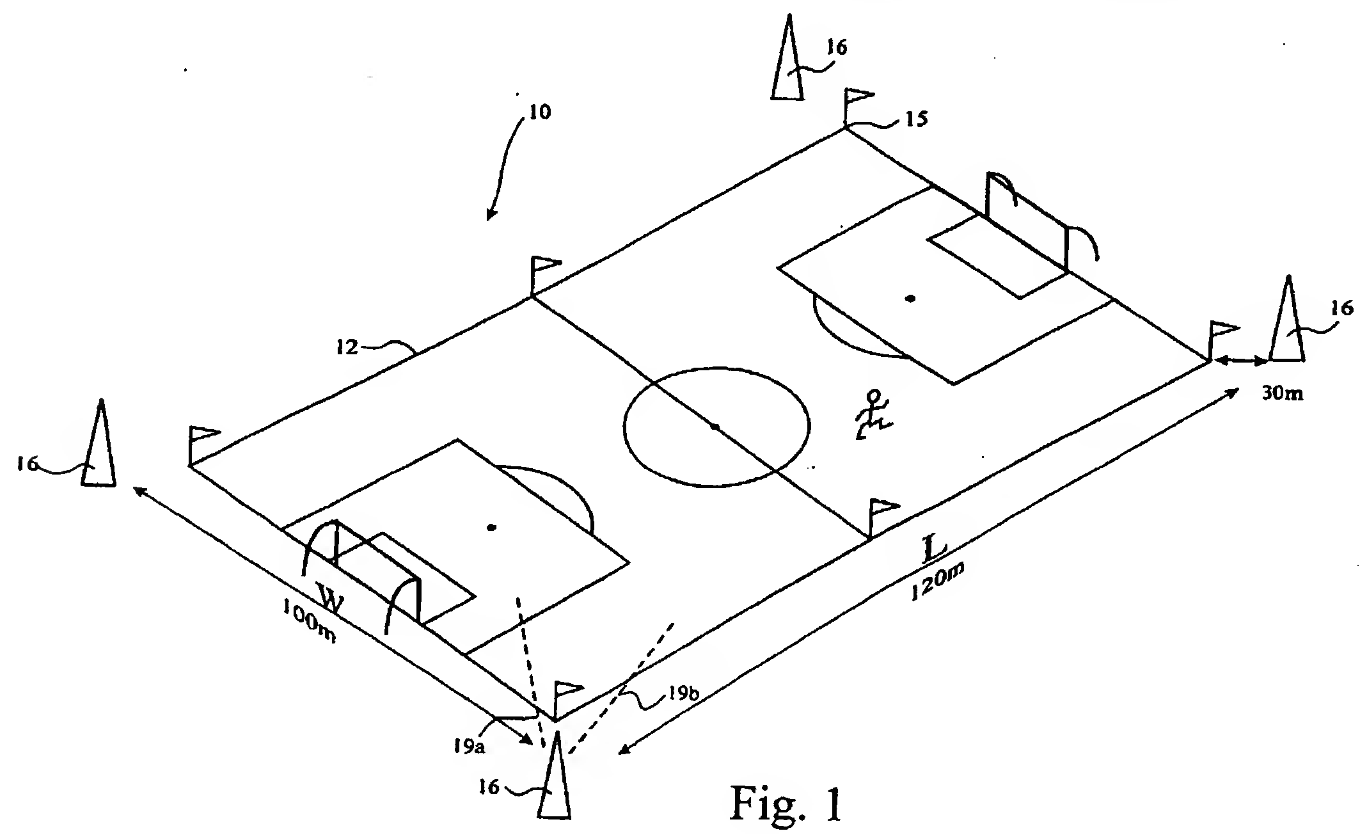


Fig. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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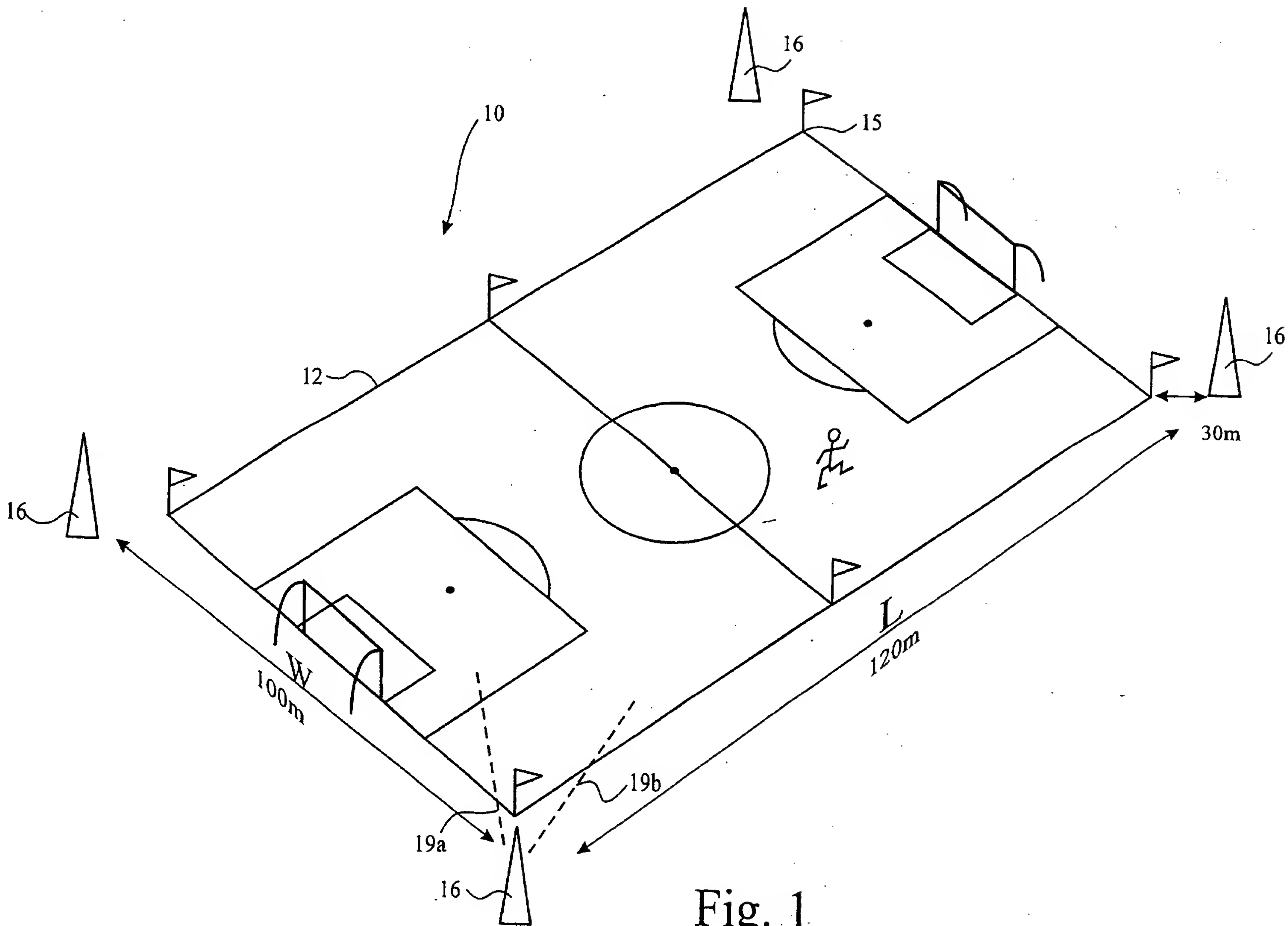



Fig. 1

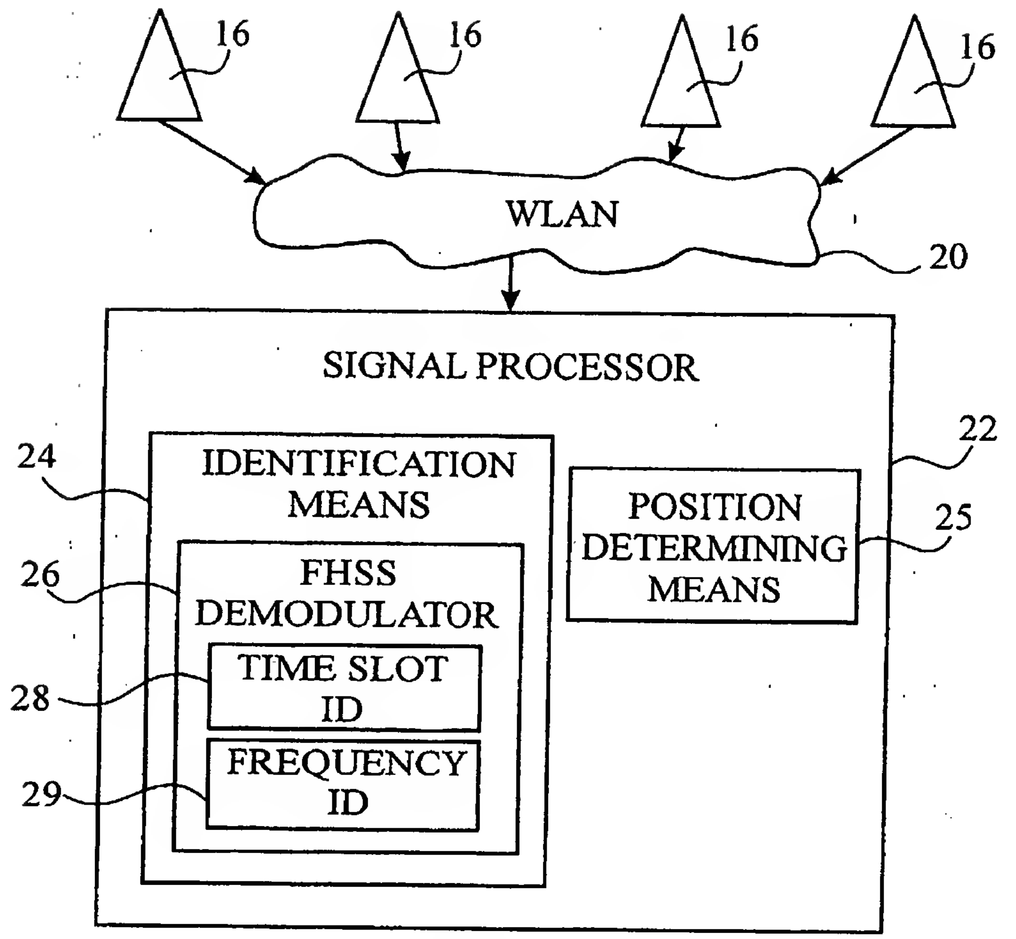

16
16
16
16
WLAN
20
SIGNAL PROCESSOR
22
24
IDENTIFICATION MEANS
POSITION DETERMINING MEANS
25
26
FHSS DEMODULATOR
28
TIME SLOT ID
29
FREQUENCY ID

Fig. 2

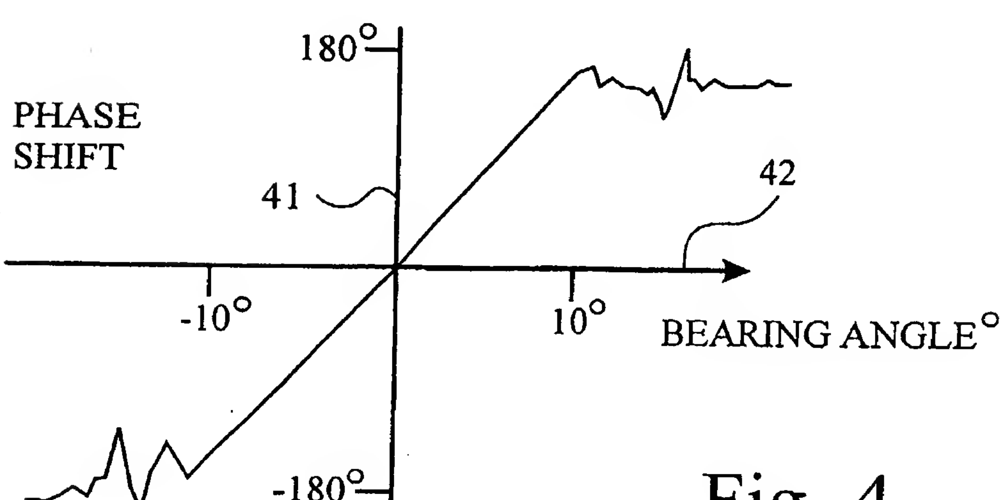
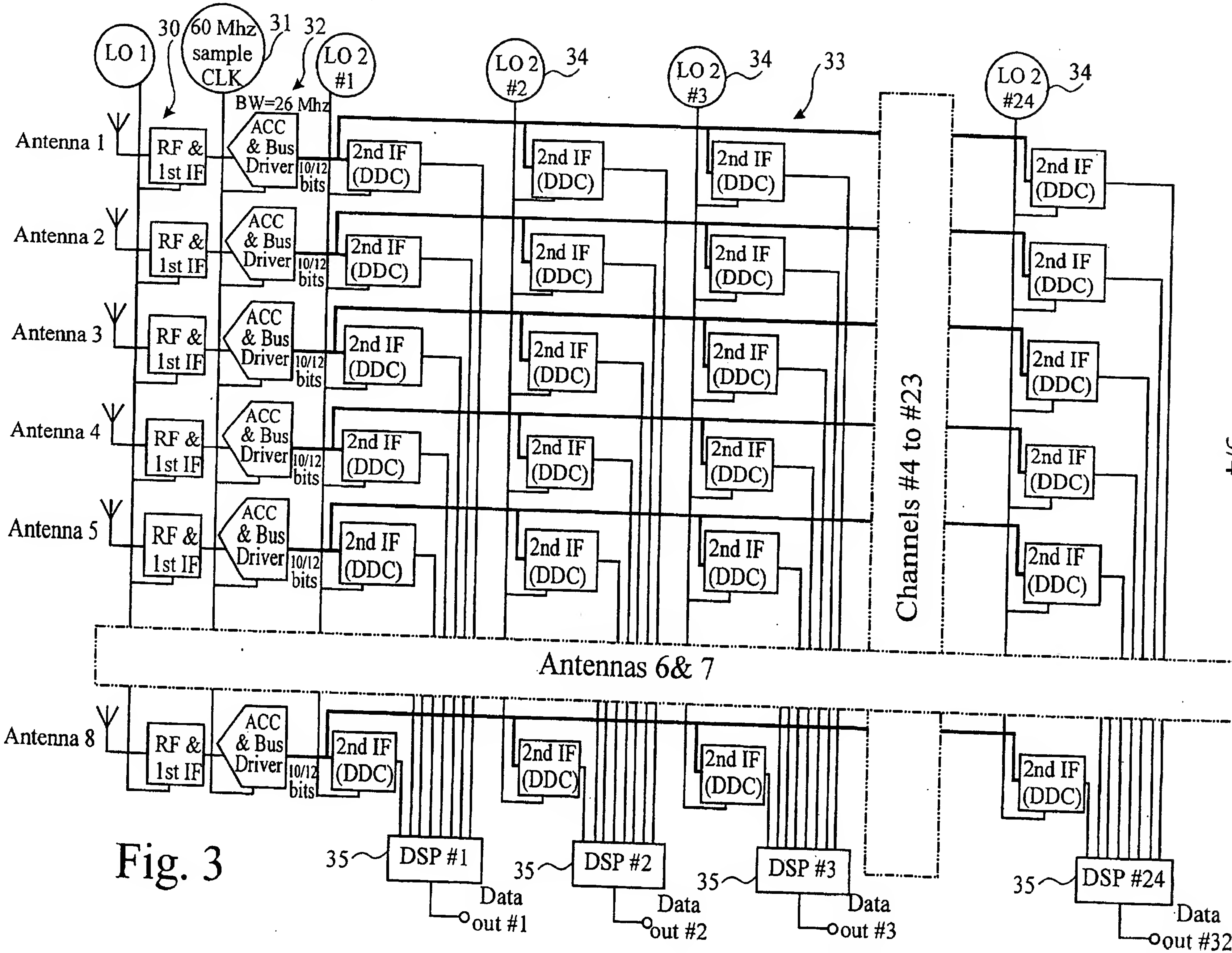

180°
PHASE SHIFT
41
42
-10°
10°
BEARING ANGLE°
-180°

Fig. 4



LO 1
60 Mhz sample CLK
30
31
32
LO 2 #1
BW=26 Mhz
LO 2 #2
LO 2 #3
LO 2 #24
34
33
Antenna 1
Antenna 2
Antenna 3
Antenna 4
Antenna 5
Antenna 8
RF & 1st IF
ACC & Bus Driver
10/12 bits
2nd IF (DDC)
Channels #4 to #23
Antennas 6& 7
35
DSP #1
DSP #2
DSP #3
DSP #24
Data out #1
Data out #2
Data out #3
Data out #32


Fig. 3

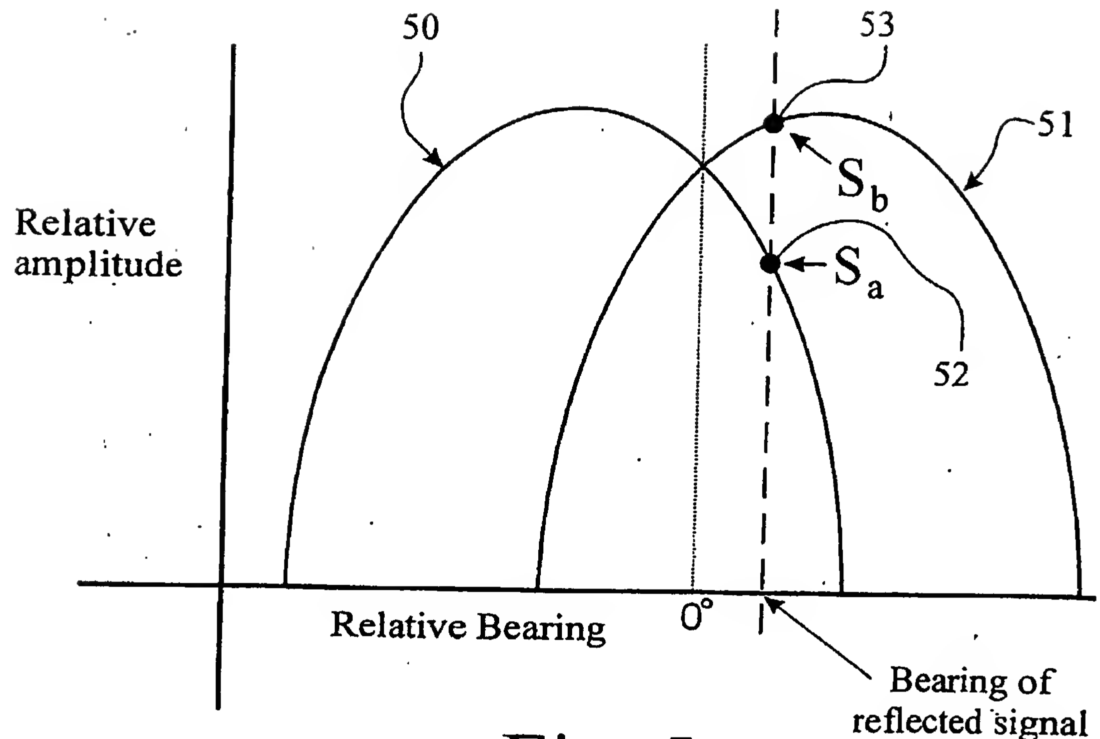

50
53
51
$S_b$
Relative amplitude
$S_a$
52
Relative Bearing
0°
Bearing of reflected signal

Fig. 5

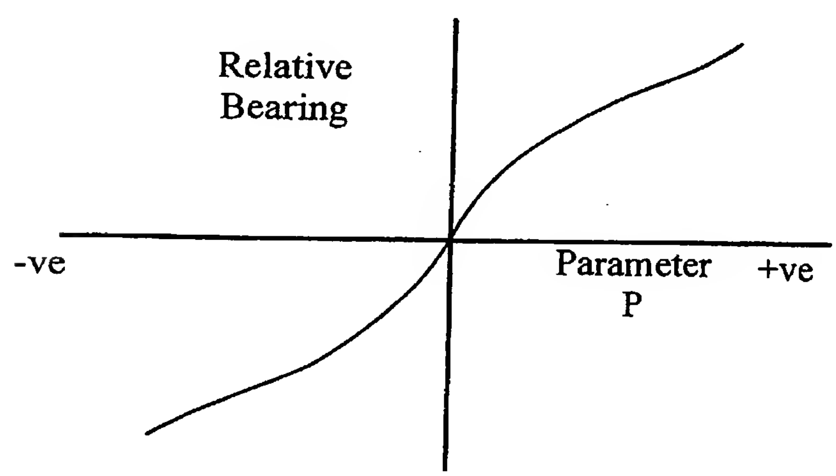

Relative Bearing
-ve
Parameter P
+ve

Fig. 6

# POSITION LOCATION SYSTEM

The present invention relates to a position location system and in particular concerns a position location system for a sports tracking system.

Developments in communication technology have provided various position location systems for both global, regional and local area position determination. The majority of these systems have been developed for navigation but in recent years it has been proposed to use local low powered systems for tracking purposes. One application is sports tracking where the system is used to calculate the real time position of a participant such as an athlete or a player on a field of play.

One sports tracking system has been developed in which each player or athlete wears a lightweight transceiver which sends a signal to fixed position antennas surrounding the field of play. The system operates at 2.45 GHz and can also use spread spectrum radio so that the signals can operate in the presence of other signals in the same general frequency band. Spread spectrum also has the advantage that it allows the system to operate within unlicensed frequency bands. A player's position is calculated from the time of arrival of the transmitted signal at each antenna receiver. Measurements are made thirty times per second for all the players on the field so that a dynamic model of the action of the players on the field can be determined. Post processing allows motion characteristics such as speed, acceleration and the like to be determined from the position location information for both players and the ball or

other target of play. The system has been developed both as a coaching tool and also to provide statistical information to enhance spectator enjoyment and interactive participation.

There are a number of drawbacks associated with sports tracking systems where location is based on the time of arrival of the transmitted signal at the respective antennas, and also where multiple-access signaling such as spread spectrum is used.

Multiple-access systems such as the spread spectrum system described above assign dedicated channels to multiple users through bandwidth division. In typical multi-node radio systems, including known player location systems, a radio frequency transceiver is required at each node. This enables all nodes to be time and/or frequency and/or phase locked to a master node, so that all nodes can be synchronised. For example, with TDMA (time division multiple access) each node must transmit in a pre-determined time slot, and therefore all the nodes must be synchronised and share the same clock. Similar requirements exist for other multiple-access methods, for example in CDMA (code division multiple access), to allow centralised power control of each node, and in FDMA (frequency division multiple access), to allow precise spacing of frequency channels without the requirement for high accuracy on-board frequency references.

The requirement for a transceiver at each node is a major drawback for position location systems such as player location systems where simple, lightweight, miniature, low power wearable tag like transmitters are required. Know systems

require a radio receiver on each tag. This is a significant disadvantage since the receiver is typically the most complex component of a radio system, and in low power applications, such as the above mentioned sports tracking system, the receiver typically consumes a significant amount of the battery power leading to oversize, overweight wearable battery powered devices. In sports tracking applications in particular it is necessary for the wearable transmitter device (transceiver) to be as small, light and non-intrusive as possible so that it does affect the player's performance or become uncomfortable to wear during the period of play.

Radio-based player location systems typically operate in unlicensed spectrum, where ample bandwidth is available, but significant levels of interference exist. Spread spectrum modulation is commonly used to promote spectrum sharing between unlicensed users without interference. One aspect of the present invention modifies standard FHSS (frequency hopping spread spectrum) techniques. However, other aspects of the invention are applicable to a system operating in licensed spectrum, where bandwidth is typically limited, but interference is well controlled.

Another drawback associated with known time of arrival based sports tracking systems is that it is necessary to measure the time of arrival of the signal to a few nanoseconds to obtain a positional accuracy of 0.5 m, one nanosecond being equal to 0.3 m in free space. In this respect, receiving equipment such as the antennas must be positioned to at least the same degree of accuracy. In a system having three antenna receivers, it is necessary to position the receivers to an accuracy of 25 cm or less to achieve player position accuracy of 0.5m. For playing fields where the receivers are

mounted on towers at the corners of the playing area antenna spacing can be up to 200 m. Considerable effort is required therefore to achieve a positional accuracy of 25 cm or less in such an arrangement. This level of accuracy is also required throughout the whole of the system including the cabling from the receivers to a common signal processor for measuring the time of arrival of the signal. This degree of accuracy cannot be readily achieved and the system does not lend itself to be moved between different stadium and/or training grounds.

The accuracy of the measurements is also determined by the signal to noise ratio at the receiver and the product of the bandwidth and the integration time of the signal at the receiver. The signal to noise ratio is determined by the transmit power of the transmitter which is itself determined by the available power from an acceptable battery weight. The integration time at the receiver is limited by the requirement to accommodate all players, the requirement to minimise transmit power and the requirement to update the player position at least ten times per second.

There is a requirement for a position location system in which absolute transmitter synchronisation is not required.

There is a further requirement for a lightweight, low-power, wearable device for use in a position location system in which each device can be individually identified

There is also a requirement for a positional location system in which each transmitter can be readily identified in a shared bandwidth multiple access radio system

independently of transmitter synchronisation.

There is a further requirement for a position location system in which a plurality of transmitters share limited radio spectrum bandwidth independently of absolute transmitter synchronisation.

According to one aspect of the invention there is provided a position location system for determining the relative position of a plurality of mobile transmitters in a designated monitored space; the said system comprising:

a plurality of asynchronous radio frequency transmitters for signal transmission on shared frequency channels and attachment to respective mobile units in the said designated monitored space;

at least two radio frequency receivers positioned in the region of the said transmitters and fixed with respect to each other for receiving asynchronous transmitted signals from the said transmitters on the said channels; the communication link between each transmitter and the receivers being a one way simplex link for transmission from the transmitter to receivers only;

a signal processor connected to the said receivers and including identifying means for identifying received asynchronous signals with respective transmitters and position determining means for determining the position of the respective transmitters with respect to the receivers. In this way the transmitter can be simplified since communication is asynchronous and therefore no associated receiver is required with the transmitter for receiving synchronisation signals from the signal processor or other control means. This aspect of the invention readily enables the mobile unit

transmitters to be smaller so that they are less intrusive and consume less power thereby improving battery life or increasing the strength of the transmitted signal.

Preferably, each transmitter comprises spread spectrum modulation means and the said signal processor comprises spread spectrum demodulation means.

Spread spectrum modulation is commonly used to promote spectrum sharing between unlicensed users where significant bandwidth is available but significant levels of interference exist. However, the system is also applicable to licensed spectrum operation where bandwidth is more limited.

In preferred embodiments, the said spread spectrum modulation and the said demodulation means comprise respective frequency hopping modulation and demodulation means. In spread spectrum frequency hopping the available radio spectrum is divided into appropriate frequency channels and each transmitter transmits sequentially over all frequency channels using a pseudo-random coded sequence. The coded sequence requires each transmitter to transmit on each channel once only in a hopping cycle.

Preferably, the modulation means for each transmitter comprises a unique modulation spreading code. This readily enables the signal processor to identify hopping sequences from a sequence of transmissions and thereby identify each transmission with a respective transmitter.

In preferred embodiments, the said identifying means comprises a modulation spreading code identification means. This readily enables hopping sequences to be identified with respective transmitters when a plurality of asynchronous hopping sequences are being transmitted simultaneously.

Preferably, the said identifying means comprises a time slot identification means for identifying respective periodic signal transmission sequences with respective transmitters. In this way it is possible to identify transmissions from the same transmitter if the transmissions are in an exact number of hop periods apart.

In preferred embodiments, the said identifying means comprises a frequency identification means for identifying the frequency of each respective transmitted signal and comparing the said signal with the desired channel frequency and means for identifying respective periodic signal transmission sequences with respective transmitters in accordance with the respective identified frequency differential for each transmitter. By measuring the exact frequency of each transmission further transmitter specific information can be obtained. The transmitters are asynchronous and therefore are not frequency locked and will therefore drift from the nominal channel frequency by different amounts because of the inherent limitations of the frequency reference means on the transmitters. The frequency differential from the nominal frequency for each transmitter will be specific for that transmitter irrespective of the transmitting frequency but measurably different to the frequency differential of the other transmitters.

Preferably, the ratio of transmitters to radio frequency channels is at least 2:1. The ratio may be in the range 2:1 to 4:1. In this way it is possible to reduce the number of collisions arising from the asynchronous nature of the transmissions from the transmitters. If the ratio of the number of channels to the number of transmitters is sufficiently high the number of transmissions lost will be small, for example less that 10%.

Preferably, the duty cycle of the said transmitted signals is substantially in the range 5-50%. In preferred embodiments the duty cycle is in the region of 10%. If the transmitters only transmit for a relatively small portion of each frequency or period, for example a 10% duty cycle, the number of collisions can be further reduced. In this way it is also possible to reduce the average power consumption so that the peak transmitted power can be increased and the signal strength improved.

Preferably, the said position determining means comprises a bearing resolution means for determining the bearing of the respective transmitted signals with respect to at least two receivers. In this way it is possible to obtain a position in two-dimensional space using a pair of receivers. More receivers can be used to obtain positional data in three-dimensional space or if greater accuracy is required.

In preferred embodiments, each receiver comprises at least two receiver elements spaced apart by one or more half wavelengths of the transmitted signal, and the said bearing resolution means includes means for processing respective transmitter signals received by the respective receiver elements to determine the bearing of the respective

transmitters with respect to the receiver elements. By making use of two or more receive elements it is possible to obtain an accurate bearing of the transmitted signal. This may be achieved, for example, by the method of processing the relative phase of the returning signal across the receive elements, or in an alternative embodiment by the method of comparing the amplitude of the return signal from two or more receive beams which are aligned at slightly different bearings. Half beam processing of reflected radar signals can provide relatively accurate positional data and it is envisaged that accuracies of 0.1 degrees should be possible with the above system.

In another aspect of the invention a sports tracking system comprises a position location system according to the above mentioned first aspect of the invention.

In a further aspect of the invention there is a method of determining the position of a plurality of mobile transmitters in a designated monitored space: the said method comprising the steps of:

transmitting asynchronous radio frequency signals on a plurality of shared radio frequency channels from a plurality of mobile transmitters in the said designated monitored space;

providing at least two radio frequency receivers at positions in the region of the said transmitters and fixed with respect to each other;

receiving asynchronous transmitted signals from the said transmitters on the said shared channels;

transmitting the respective received signals to a signal processor connected to the said receivers;

identifying the respective received asynchronous signals with respective transmitters; and,

determining the position of the respective transmitters with respect to the receivers.

In a further aspect of the invention there is a method of calibrating a position location system; said method comprising the steps of:- (i) transmitting a calibration signal at a plurality of pre-determined positions in a calibration space; the signal being received by at least two receivers positioned in the region of the said calibration space; each calibration signal being modulated using a frequency hopping spread spectrum codes; (ii) demodulating the said calibration signals received by each receiver and identifying each calibration signal with a respective transmitter at a respective pre-determined position in the said calibration space; determining positional data relating to the bearings of the received signal for each of the said pre-determined positions with respect to each receiver; and storing the said data with position identification reference data for subsequent retrieval and position location determination.

In preferred embodiments transmitters are positioned at pre-determined positions on the playing field, for example at the corners of a rectangular football field, so that bearings from each of the receivers can be determined for each transmitter. The relative position of the mobile transmitters can then be related to the field of play as determined by the static calibration transmitters.

Various embodiments of the invention will now be more substantially described, by

way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a playing field comprising ground markings for the game of association football or soccer;

Figure 2 is a block diagram of a signal processor connected by a communications network to a plurality of distributed radio antenna receivers;

Figure 3 is a schematic view of the phase relationship for a half beam processor for determining an angular bearing;

Figure 4 is a block diagram of a wideband frequency hopping spread spectrum receiver for a position location system according to an embodiment of the present invention;

Figures 5a and 5b show respective amplitude and phase angle relationships for transmitted radio signals at the receivers in the time domain;

Figure 6 is a schematic representation of the relative amplitude and relative bearing characteristics of two antenna receive beams; and

Figure 7 is a schematic representation of the relative bearing characteristic determined from the beam pattern to receive antennas.

Referring to Figure 1, a sports playing field indicated at 10 comprises a series of ground marking in the form of lines 12 which define a designated playing area, in this embodiment for the game of association football or soccer. The playing area 14 may constitute part of a sports stadium or open training field. The playing area 14 has a length indicated by the dimension "L" of approximately 120 metres and a width indicated by the dimension "W" of approximately 100 metres. A radio tower 16 is positioned at each corner of the playing area 14 approximately 30 metres from the

corner position 15. Each radio tower 16 comprises an antenna assembly having a linear array of eight antenna elements at half-wave length spacing as determined by the operating frequency of the system. As will be explained in more detail below. The radio towers and receivers comprise part of a position location system for determining the positions of players 18, match officials, and the ball or other movable target play on the playing area 14. The antenna elements comprise part of a radio frequency receiver (not shown) at each tower location with each pair of antenna receiver elements providing a beam width of approximately 20 degrees across the playing area 14. The four antenna beams provided by the four pairs of antenna receiver elements overlap partially by approximately 1 to 3. degrees to provide overlapping beam coverage of approximately 60 to 80 degrees, but preferably about 66 degrees. The outer arcs of the overlapping antenna receive beams are indicated by the broken lines 19a and 19b in the drawing of Figure 1.

The players 18, match officials, and ball or other means are each provided with a low power light weight asynchronous radio transmitter which has a transmit only capability. Each transmitter includes appropriate circuitry and/or software for implementing frequency hopping spread spectrum multiple access signal modulation so that a plurality of such transmitters can share limited radio spectrum, where the number of frequency channels is less than the number of transmitters. It is to be appreciated that frequency hopping spread spectrum modulation is equally applicable for operation in unlicensed frequency bands where interference with other systems can exist and also in licensed spectrum where bandwidth is limited but interference is controlled.

The transmitter units are relatively small and weigh approximately 20 grams or less including battery weight and therefore may be sewn into the player's or match official's clothing so that the position of those individuals can be tracked by the receiver units using phase correlation methods to obtain a bearing on each player or match official's transmitter. By using two or more receivers it is possible to combine the bearing from each receiver to provide a location for each transmitter (player/match official or ball or other means). In this way as the players, match officials and ball move on the playing area the relative bearings of the transmitters to the receivers are measured. The operational frequency of the position location system may be in the high 100's MHz frequency range or in the GHz range. For instance in a position location system suitable for operation in the United States unlicensed band of 902 to 928 MHz a radio frequency bandwidth of 26 MHz can be used to support approximately ninety transmitters.

Referring to Figure 2, the eight receive antenna elements on each radio tower 16 are connected by means of a wireless local area network (WLAN) 20 to a signal processor 22 or base station which may comprise a PC or other processing means. The signal processor 22 comprises two main components including a transmitter identification means 24 and a position determining means. The identification means 24 implements a frequency hopping spread spectrum demodulation means 26 for identifying the frequency hopping spread spectrum pseudo-random coded sequence for each respective transmitter. It is to be understood that in frequency hopping spread spectrum systems available radio spectrum is divided into a plurality of frequency

channels and each transmitter transmits sequentially over all frequency channels using a pseudo-random coded sequence that is unique to that transmitter. In a hopping cycle each transmitter transmits on all channels once only. The transmitter identification means 24 demodulates the received pseudo-random sequences to identify the received sequences with particular transmitters.

In the position location system of the present invention the transmitters are asynchronous, that is to say the communication link between each transmitter and the receivers is a one way simplex link for transmission from the transmitter to the receivers only. There is no communication from the receivers to the transmitters and therefore synchronisation of the transmissions is not possible.

Because all the transmitters are asynchronous, there will be a significant number of collisions in use. However, if the ratio of the number of channels to transmitters is sufficiently high, the amount of location data lost due to collisions will be acceptable, less than 10% say. Furthermore, if the transmitters only transmit for a portion of each frequency hop, for example a 10% duty cycle, the number of collisions will be reduced still further. Reducing the duty cycle has the additional benefit that, for a given average current consumption, the peak transmit power can be increased and therefore the range and signal strength of the transmitted signal.

Since the transmitters all share the same set of frequencies, the receiver cannot deduce from an individual transmission the identity of the tag without further processing in this FHSS demodulator 26. However, as will be appreciated a sequence of

transmissions allows the signal processor to identify hopping sequences, and hence the identity of each individual transmission. The task of identifying sequences and transmitters is relatively complex. Since several asynchronous hopping sequences occur simultaneously. The signal processor of Figure 2 implements a number of methods to allow the processor to identify and then track each transmitter with the minimum delay:

In use, the identification means 24 surveys all incoming transmissions, and then eliminates transmitters that could not have caused a particular transmission, that is to say by coarsely filtering the incoming transmissions on the basis of a number of selection criteria, for example position location at least transmission.

The exact timing of frequency hops for each transmission is measured by a time slot identification means 28. The position in time of an individual transmission provides transmitter-specific information that is used by the exclusion algorithm in the signal processor. This part of the algorithm is based on the fact that each transmitter has a constant hop rate, but is asynchronous to other transmitters. Therefore two transmissions, say 10 hops apart, can only be from the same transmitter if they are exactly 10 hop periods apart.

The exact frequency of each transmission is measured by a frequency identification means 29, this provides further transmitter-specific information. The transmitters are not frequency locked since they have no receiver so they drift off the nominal channel frequency because of the inherent limitations of a frequency reference device on each

transmitter. The frequency differential (Δf) the nominal frequency for any transmitter is the same for all transmissions, whatever the frequency, but will be different to the exact Δf of all other transmitters. Thus, two transmissions can only be from the same transmitter if their Δf is the same. This is also implemented in the exclusion algorithm.

Once all the transmitters have been identified, a conventional tracking algorithm implemented in the identification means is used keep the receiver synchronised to each transmitter.

Referring now to Figure 3, which shows an architecture suitable for operation in the US 902-928MHz unlicensed band, with an RF bandwidth of ~26MHz, and supporting 90 transmitters. Signals from the eight antennas are coherently down-converted to 1st-IF means 30, filtered then sampled at approximately 60MHz by sampler clock means 31. Each ADC 32 output is buffered and routed to 24 2nd-IF stages 33, which are Digital Down Converters (DDC's). Each column of DDC's is fed by a Local Oscillator (LO234). All LO2's have their frequency set by a control processor, which is tracking the hopping pattern of all of the transmitters.

At any instant in time, each column of DDC's is be tuned to the frequency of a particular transmitter. Eight coherently down-converted signals, one for each antenna, are then passed to a DSP 35, which performs an FFT to reduce the bandwidth from 25KHz to 300Hz, and phase comparisons on the eight signals, and extracts the respective bearing. The loading on the DSP is light, so an inexpensive component can

be used. A tracking and predicting algorithm, running on a control processor, continuously selects the most appropriate frequency for each of the 32 available channels.

Note that in the example system there are up to 90 transmitters in use, but only 24 receive channels available. This is possible because a technique for time-sharing the DDC's has been devised. The transmitters are transmitting asynchronously, with a 10% duty cycle, so during any given timeslot there are, on average, only 18 transmitters active. The number of available DDC's (and hence receive channels) is selected to make the probability of not having enough receivers available at any time acceptably low (around 5%). This time-sharing of the DDC's allows significant reduction in hardware requirements.

In the embodiment described the position location system comprises a plurality of transmitters 18 and arrays of eight receiver elements. The elements are spaced apart horizontally in a plane above the ground plane of the playing area to be monitored to provide a directional antenna system which covers arcs of at least 66 degrees as shown by the beam arcs 19a and 19b. In preferred embodiments a beam angle of between 60 and 80 degrees should be sufficient to cover the area of the playing field.

Referring to Figure 4, in one embodiment the position determining means 26 in the signal processor 23 comprises a half beam processor for processing the radio signals received at the receiver elements. The bearing of the transmitter with respect to a notional axis 40 of a receiver element pair, as indicated by angle 41, is determined

by the phase relationship of the transmitted signal at the respective receiver element pair.

The relationship between the bearing 41 and the phase difference of the transmitted signal is shown in Figure 4. As can be seen in Figure 4, for small angles 41, say plus or minus 10 degrees there is an approximate near linear relationship between the phase difference 42 of the respective receivers and the bearing angle 41. In this way it is possible to determine the bearing of a transmitter transmitting a signal to the receiver elements in accordance with the phase relationship of the transmitted signals at the receivers.

Referring now to Figure 5, in an alternative embodiment the two receivers elements are steered at slightly different angles with respect to one another and the signal processor 22 comprises appropriate circuitry and/or software for comparing the amplitude of the transmitted signal from the receive beams at the receiver elements. In Figure 5, the relative amplitude and relative bearing characteristics of two receive beams 50 and 51 are shown for the respective receiver elements. As can be seen in Figure 5, on measuring the relative amplitude, that is the signal strength, of the signal in each beam 50 and 51, say the amplitude $S_a$ at point 52 on beam 50 and the amplitude $S_b$ at point 53 in beam 51, it is possible to obtain the bearing of the transmitter from the relative amplitude of the respective transmitted signals. The relative amplitudes $S_a$ and $S_b$ are normalised with respect to the absolute and amplitude by means of the following equation.

$P = (S_a - S_b)/(S_a + S_b)$

Where P is the normalised parameter.

Once the value of P has been calculated it is possible to determine the relative bearing of the transmitter using the bearing characteristic shown in Figure 6. The characteristic shown in Figure 6 is determined from the beam pattern of the receivers.

Although aspects of the invention have been described with reference to the embodiments shown in the accompanying drawings it is to be understood that the invention is not limited to those precise embodiments and various changes and modifications may be affected without exercise of further inventive skill for example, the position location system may be applied to any sport where an element of tracking is desired.

## CLAIMS

1. A position location system for determining the relative position of a plurality of mobile transmitters in a designated monitored space; the said system comprising:

a plurality of asynchronous radio frequency transmitters for signal transmission on shared frequency channels and attachment to respective mobile units in the said designated monitored space;

at least two radio frequency receivers positioned in the region of the said transmitters and fixed with respect to each other for receiving asynchronous transmitted signals from the said transmitters on the said channels; the communication link between each transmitter and the receivers being a one way simplex link for transmission from the transmitter to receivers only;

a signal processor connected to the said receivers and including identifying means for identifying received asynchronous signals with respective transmitters and position determining means for determining the position of the respective transmitters with respect to the receivers.

2. A system as claimed in Claim 1 wherein each transmitter comprises spread spectrum modulation means and the said signal processor comprises spread spectrum demodulation means.

3. A system as claimed in Claim 2 wherein the said spread spectrum modulation and the said demodulation means comprise respective frequency hopping modulation and demodulation means.

4. A system as claimed in Claim 3 wherein the modulation means for each transmitter comprises a unique modulation spreading code.

5. A system as claimed in Claim 4 wherein the said identifying means comprises a modulation spreading code identification means.

6. A system as claimed in Claim 4 or Claim 5 wherein the said identifying means comprises a time slot identification means for identifying respective periodic signal transmission sequences with respective transmitters.

7. A system as claimed in any one of Claims 4 to 6 wherein the said identifying means comprises a frequency identification means for identifying the frequency of each respective transmitted signal and comparing the said signal with the desired channel frequency and means for identifying respective periodic signal transmission sequences with respective transmitters in accordance with the respective identified frequency differential for each transmitter.

8. A system as claimed in any preceding claim wherein the ratio of transmitters to radio frequency channels is at least 2:1.

9. A system as claimed in any preceding claim wherein the duty cycle of the said transmitted signals is substantially in the range 5-50%.

10. A system as claimed in any preceding claim wherein the said position determining means comprises a bearing resolution means for determining the bearing of the respective transmitted signals with respect to at least two receivers.

11. A system as claimed in Claim 10 wherein each receiver comprises at least two receiver elements spaced apart by one or more half wavelengths of the transmitted signal, and the said bearing resolution means includes means for processing respective transmitter signals received by the respective receiver elements to determine the bearing of the respective transmitters with respect to the receiver elements.

12. A sports tracking system comprising a position location system as claimed in any preceding claim.

13. A method of determining the position of a plurality of mobile transmitters in a designated monitored space: the said method comprising the steps of:

transmitting asynchronous radio frequency signals on a plurality of shared radio frequency channels from a plurality of mobile transmitters in the said designated monitored space;

providing at least two radio frequency receivers at positions in the region of the said transmitters and fixed with respect to each other;

receiving asynchronous transmitted signals from the said transmitters on the said shared channels;

transmitting the respective received signals to a signal processor connected to the said receivers;

identifying the respective received asynchronous signals with respective transmitters; and,

determining the position of the respective transmitters with respect to the receivers.

14. A method of calibrating a position location system; said method comprising the steps of:- (i) transmitting a calibration signal at a plurality of pre-determined positions in a calibration space; the signal being received by at least two receivers positioned in the region of the said calibration space; each calibration signal being modulated using a frequency hopping spread spectrum codes; (ii) demodulating the said calibration signals received by each receiver and identifying each calibration signal with a respective transmitter at a respective pre-determined position in the said calibration space; determining positional data relating to the bearings of the received signal for each of the said pre-determined positions with respect to each receiver; and storing the said data with position identification reference data for subsequent retrieval and position location determination.

15. A system substantially as hereinbefore described and with reference to the accompanying drawings.

16. A method substantially as hereinbefore described and with reference to the accompanying drawings.

**Application No:** GB 0131098.6
**Claims searched:** 1 to 13

**Examiner:** Dr E.P. Plummer
**Date of search:** 23 September 2002

## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4D (DPAA, DPAB, DPAC, DPAX, DAB)

Int Cl (Ed.7): G01S 5/04, 5/06

Other: Online: WPI, PAJ, EPODOC

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| X | GB2337385A | Lyden<br>whole document<br>nb reference to triangulation | 1,8,12,13 |
| X | GB2332112A | Motorola<br>whole document | 1,2,8,9,<br>10,13 |
| X | GB2330716A | Motorola<br>whole document | 1,8,9,13 |
| X | GB2253107A | Philips<br>whole document | 1,8,10,13 |
| X | GB1333849 | Hazeltine<br>whole document | 1,2,8,13 |
| X | EP0807828A1 | CNRS<br>whole document | 1,8,12,13 |
| X | WO2001/66201A1 | CAIROS<br>whole document | 1,8,12,13 |

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|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

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**Application No:** GB 0131098.6
**Claims searched:** 1 to 13

**Examiner:** Dr E.P. Plummer
**Date of search:** 23 September 2002

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| X | WO97/36771A1 | NEXUS<br>whole document | 1,2,3,8,13 |
| X | WO96/25673A1 | NEXUS<br>whole document | 1,2,3,8,13 |
| X | WO95/10337A1 | KLEIN<br>whole document | 1,8,12,13 |
| X | US5513854 | DAVER<br>whole document | 1,9,10,12, 13 |
| X | JP2001104533A | MITSUBISHI<br>whole document | 1,8,10,12, 13 |

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